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**United States
Coast Guard**

INTRODUCTION TO MAIN PROPULSION MACHINERY

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INTRODUCTION TO MAIN PROPULSION MACHINERY

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QUESTIONS ABOUT THIS TEXT SHOULD BE ADDRESSED TO THE SUBJECT MATTER SPECIALIST FOR THE MACHINERY TECHNICIAN RATING

REFERENCE

Fireman, ... NAVEDTRA 10520.G

NOTICE TO STUDENT

As a fireman aboard a ship or at a shore unit you will become familiar with the engineering plant. This plant includes main propulsion machinery and auxiliary machinery. You will also take readings on engines and assist petty officers in maintaining and repairing engines and other equipment.

This pamphlet deals with the different types of engines and fuels used aboard ships and small boats. It also includes the common terms which go with each engine and illustrations of the equipment.

The pamphlet contains one assignment and a pamphlet review quiz. The assignment is separated into topic areas. Each topic area contains a brief self-quiz. The pamphlet review quiz is located in Appendix A. The pamphlet review quiz answer key is in Appendix B.

IMPORTANT NOTE: This text has been compiled for TRAINING ONLY. It should NOT be used in place of official directives or publications. The text information is current according to the references listed. You should, however, remember that it is YOUR responsibility to keep up with the latest professional information available for your rating. Current information is available in the Coast Guard Enlisted Qualifications Manual, COMDTINST M1414.8A.

SWE STUDY SUGGESTION: Servicewide exam questions for your rate and pay grade are based on the Professional and Military Requirements sections of the Enlisted Qualifications Manual, COMDTINST M1414.8A. If you use the references from this text and consult the Enlisted Qualifications Manual, you should have good information for review when you prepare for your servicewide exam.

CONTENTS

INTERNAL COMBUSTION ENGINES

Reading Assignment: 1
Pages 1-1 through 1-30

OBJECTIVES

1. Given a list of descriptions, IDENTIFY the operation of gasoline, diesel, and gas turbine engines.
2. Given a list, IDENTIFY the operation and role of the major parts of each engine.
3. Given a list of fuels used and a list of types of engines, MATCH each fuel with the appropriate engine.
4. Given a list of descriptions, IDENTIFY the two-stroke and four-stroke cycles of a gasoline and diesel engine.

INTRODUCTION

There are three types of engines in use today:

GASOLINE
DIESEL
GAS TURBINE

The GASOLINE engine is used to drive pumps, compressors, and generators. It is used in cars, tractors, planes, and boats. A spark ignites its fuel.

The DIESEL was developed by a German between 1892 and 1897. The heat of compression ignites its fuel.

The pistons in both the gasoline and diesel engines move back and forth (or reciprocate). The engines also burn their fuels internally. Therefore, both engines are referred to as RECIPROCATING, INTERNAL COMBUSTION ENGINES.

The GAS TURBINE ENGINE is a nonreciprocating, internal combustion engine. Its main moving parts rotate on a central shaft. Rotor blades on the shaft change the force of the burning fuel into motion. A spark ignites the fuel until the engine warms up. The engine's own heat ignites the fuel after that.

FUELS

Most engine fuels are made from crude oil. To burn well, they must be mixed with air.

Gasoline is a common fuel. It is a light, but costly fuel. All but a few impurities are refined out. It readily gives off vapors. At very low temperatures it will ignite and burn. It is a serious fire hazard wherever used. It MUST be handled with care. Its ignition features are rated by OCTANE number.

DIESEL fuel is heavier and cheaper than gasoline. It has many more chemical impurities. At normal temperatures it doesn't give off burnable vapors. It is far less of a fire hazard. Diesel fuel is used in diesel engines and in gas turbine engines. Its ignition features are rated by CETANE number.

Gas turbine engines also use JET FUEL. Gas turbines will run on just about any fuel that will burn. This doesn't mean that some fuels won't make them run better than other fuels will. This is where diesel fuel and common JP-5 jet fuel come in.

Although both fuels do the job, JP-5 is preferred for use in gas turbine engines. It is a pure, high grade kerosene. It is fairly safe to handle. It is more expensive than diesel fuel, but cheaper than gasoline.

Coast Guard ships do not have one fuel system for their diesels and another for their gas turbines. They take aboard which ever fuel is the most readily available, even though diesel is the preferred, all-around fuel.

The cutters that are designed to take helicopters aboard do have two fuel systems: the main ship's system for diesel fuel and the JP-5 system for fueling the helicopters. If, for some reason, the ship runs low on diesel fuel, it can pump the JP-5 into the diesel tanks and keep right on going.

THE GASOLINE ENGINE

The gasoline engine works very simply. A PISTON moves in a CYLINDER whose upper end is sealed. The seal is called a head and is indented to form a combustion space (chamber). PISTON RINGS seal the other end. They ring the piston and press against the cylinder wall. These prevent gases from escaping past the piston.

INTAKE VALVES in the combustion chamber let the air-fuel mixture from the CARBURETOR into the combustion chamber. An electric spark ignites the mixture. As it burns, it expands. The increased pressure forces the piston away from the head.

As the piston moves, it moves the CONNECTING ROD which moves the CRANKSHAFT. The up-and-down motion of the piston is changed to the turning motion of the crankshaft (figure 1-1).

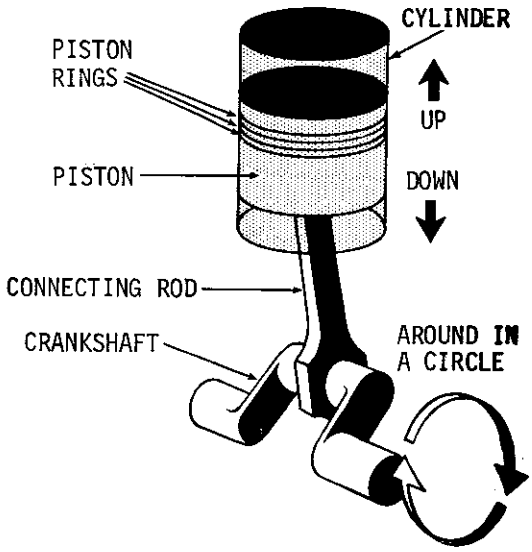


Figure 1-1. - Up-and-down motion changed to turning motion.

The piston returns toward the head, and EXHAUST VALVES let the burned gases (exhaust) out of the cylinder. The entire process is repeated as long as the engine is operating.

THE FOUR-STROKE-CYCLE GASOLINE ENGINE

In most gasoline engines, each piston moves up and down twice after each firing. This motion is divided into four strokes, each with a name and distinct function (figures 1-2, 1-3, 1-5, and 1-6).

Intake Stroke

The piston is moving DOWN in the cylinder (figure 1-2). The intake valve is open. As the piston moves downward, it draws the air-fuel mixture into the cylinder. Just before it reaches the bottom of its travel, the intake valve closes.

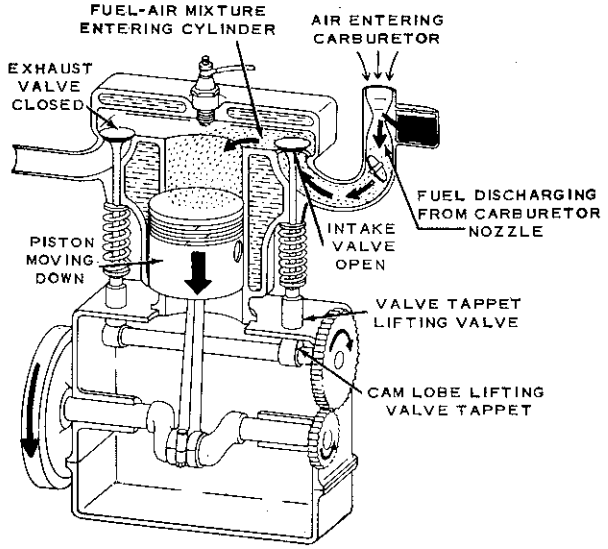


Figure 1-2. - Intake stroke of gasoline engine.

Compression Stroke

The second stroke moves the piston UP toward the top of the cylinder (figure 1-3). The air-fuel mixture cannot escape because both intake and exhaust valves are now closed. The upward moving piston compresses the mixture in the space above the piston. It is compressed to approximately 1/9th of its original volume. This is the compression ratio (figure 1-4).

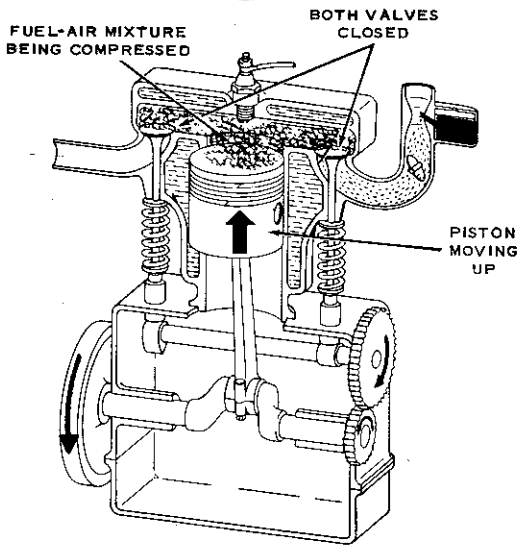


Figure 1-3. - Compression stroke in a gasoline engine.

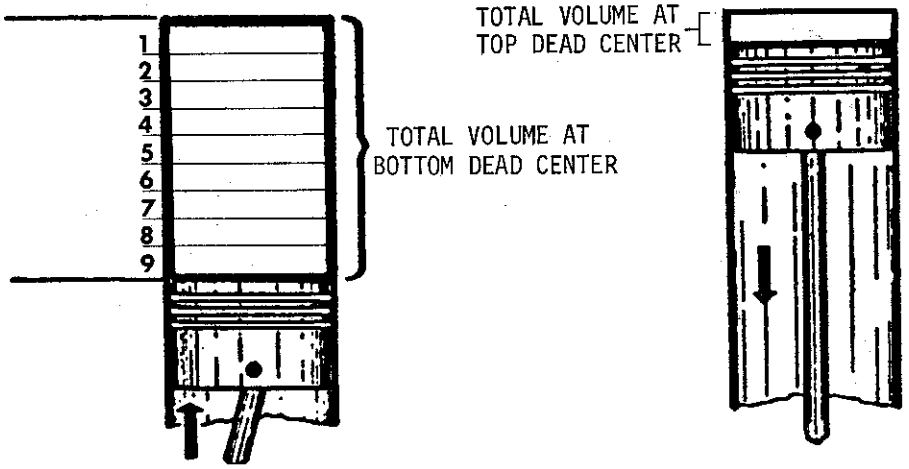


Figure 1-4. - Compression ratio shown in a gasoline engine.

Power Stroke

The third stroke is the heart of the cycle (figure 1-5). Just before the piston reaches the top of its travel, the tip of the spark plug fires an electric spark. This ignites the air-fuel mixture in the cylinder. After the piston passes dead center, the expanding gases drive the piston downward again with great force. This force is the mechanical energy that drives the crankshaft.

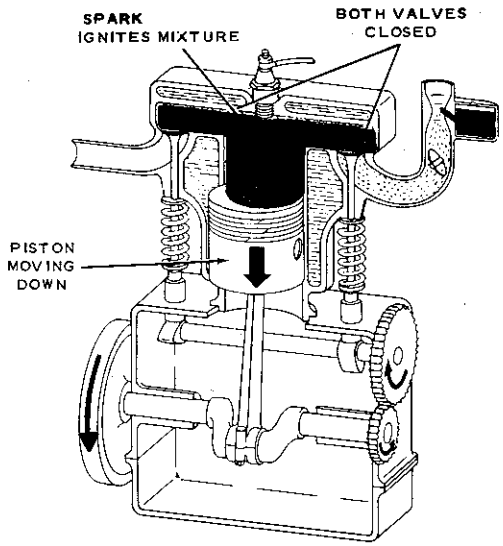


Figure 1-5. - Power stroke of a gasoline engine.

Exhaust Stroke

This is the last stroke in the cycle. After the power stroke, the exhaust valve opens. The piston returns to the top of the cylinder. As it moves upward, the burned gases are expelled into the exhaust system (figure 1-6). After the exhaust stroke, the cycle starts all over again with the intake stroke.

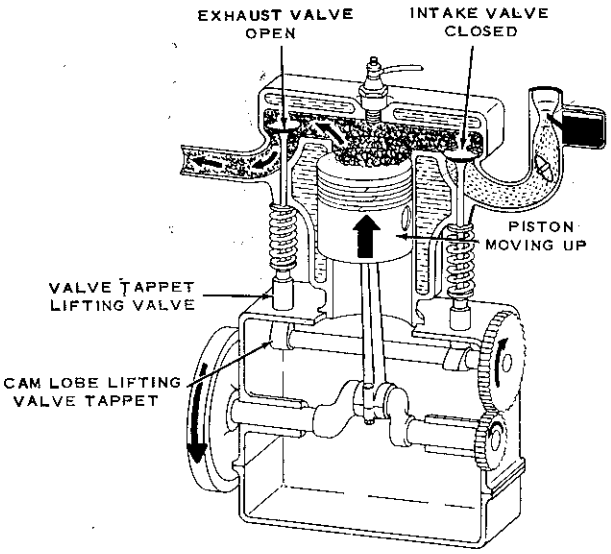


Figure 1-6. - Exhaust stroke of a four-cycle gasoline engine.

Now, before you move on, test yourself on these questions on the next page.

REVIEW QUESTIONS

1. Which internal combustion engine fuel is the most dangerous to handle?

   A. Diesel fuel
   B. JP-5 (jet fuel)
   C. Gasoline

2. In the four-stroke engine, which stroke follows the compression stroke?

   A. Intake
   B. Power
   C. Exhaust

3. The piston travels toward crankshaft on the _____and intake strokes.

4. Mechanical energy is produced in the _____stroke.

   A. intake
   B. compression
   C. exhaust
   D. power

5. When the volume of the air-fuel mixture is reduced by piston movement, an engine is in the _____ stroke.

   A. intake
   B. compression
   C. power
   D. exhaust

Circle true or false in questions 6 and 7. Correct any false statements.

6. In a four-stroke gasoline engine, the fuel enters the cylinder through the intake valves.

   TRUE/FALSE

   _____
   _____

7. In a four-stroke gasoline engine, all valves are closed during the intake stroke.

   TRUE/FALSE

   _____
   _____

ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	C. GASOLINE is far more dangerous than the others because it gives off burnable vapors at low temperatures.	1-1
2	B. In the four-stroke engine, the POWER STROKE follows the compression stroke.	1-3
3	The piston travels toward crankshaft on the POWER and intake strokes.	1-3
4	D. Mechanical energy is produced in the POWER STROKE.	1-3
5	B. When the volume of the air-fuel mixture is reduced by piston movement, an engine is in the COMPRESSION STROKE.	1-2
6	TRUE	1-2
7	FALSE. The intake valves are open. All valves are closed during the power stroke.	1-2

THE TWO-STROKE-CYCLE GASOLINE ENGINE

The four-stroke-cycle engine requires two turns of the crankshaft to complete a cycle. The two-stroke-cycle engine, however, combines the four actions of the piston (intake, compression, power and exhaust) into two strokes. Its complete cycle requires only one turn of the crankshaft.

In the two-stroke-cycle engine, the piston acts as a valve. It clears ports (openings) in the cylinder wall as it moves downward on the power stroke. It first clears the exhaust ports and the burned gases begin to leave the cylinder. Next the piston passes the intake ports and air-fuel mixture enters the cylinder. (The mixture actually consists of air, fuel, and lube oil. This will be covered later.) The inrushing mixture forces the burned gases the rest of the way out. Figure 1-7 provides a detailed description of the action.

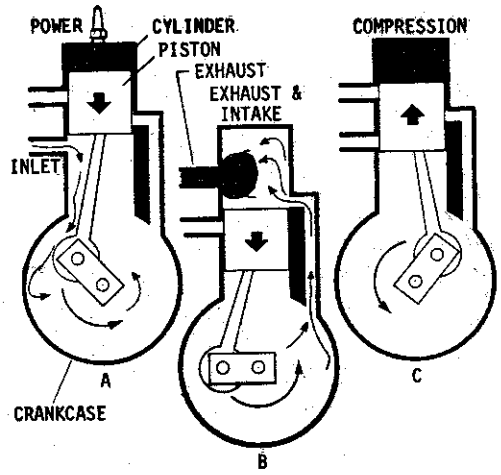


Figure 1-7. - Two-stroke-cycle action.

Power Stroke (figure 1-7A)

After the piston has compressed the air-fuel mixture in the cylinder, the spark plug fires. The high pressure of the burning gases drive the piston downward. This force is sent through the connecting rod to the crankshaft. This force continues until the piston clears the exhaust ports. But this isn't the end of the power stroke. Two more events occur just before the piston reaches the end of its downward travel.

Exhaust and Intake Events (figure 1-7B)

When the piston clears the exhaust ports, burned gases begin to leave the cylinder through them. As the piston moves past the intake ports, the inrushing air-fuel mixture pushes the rest of the burned gases out the exhaust ports. At this point, the piston has ended its downward travel and has completed the power stroke. The cylinder is now full of a fresh air-fuel mixture. Next is the compression stroke.

Compression Stroke (figure 1-7C)

After the end of the power stroke, the piston starts upward. When it has passed the intake and exhaust ports, compression begins. The fresh air-fuel mixture is compressed into a fraction of its original volume. The compression stroke ends when the piston reaches the end of its upward travel.

The two-stroke engine is unique in that every time the piston moves downward it is in the power stroke. This type of engine is used in the Coast Guard to drive some portable fire pumps. Outboard motors are of this type also.

Now test your knowledge of the information with some review questions and a crossword puzzle.

REVIEW QUESTIONS

Circle true or false in questions 1 and 2. Correct any false statements.

1. In a two-stroke engine, the intake and exhaust events occur at the end of the power stroke.

   TRUE/FALSE

   _____

   _____

2. In a two-cycle engine, every other stroke is a power stroke.

   TRUE/FALSE

   _____

   _____

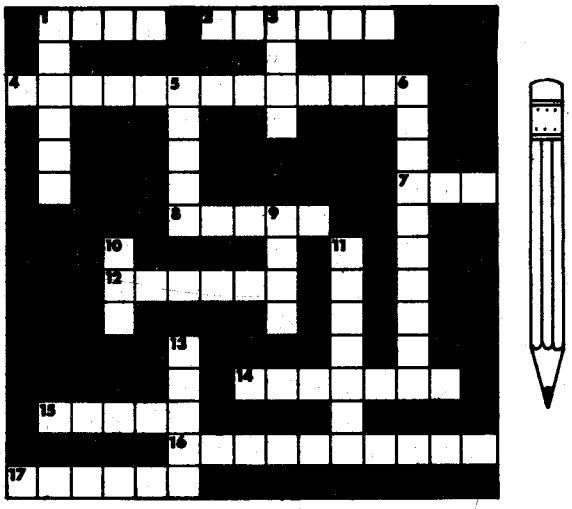
3. CROSSWORD PUZZLE

ACROSS

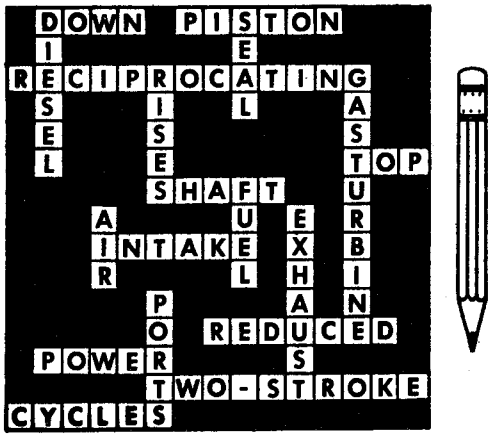
1. Piston moves this direction in intake stroke.
2. Moves within a cylinder.
4. Engine classified by this movement.
7. Piston moves toward this on compression stroke.
8. This changes rotary motion into work.
12. First engine stroke.
14. This happens to original cylinder volume.
15. Stroke used in reciprocating engines.
16. Class of engine (two words)
17. Events occurring in a running engine.

DOWN

1. Type of engine.
3. What piston rings do.
5. What temperature does as a result of compression.
6. Type of engine (two words)
9. All engines need this to run.
10. Fuel won't burn without it.
11. Burned gases.
13. Found in the cylinder walls of two-stroke-cycle engines.



ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	TRUE	1-7
2	TRUE	1-7
3		

THE FUEL SYSTEM CARBURATION

The operation of gasoline engines depends a great deal upon the air-fuel mixture. The mixture must be well atomized (broken-up) and at the proper air-fuel ratio, before it is sent to the combustion chamber. This is done by the carburetor. It is often a very simple device (figure 1-8).

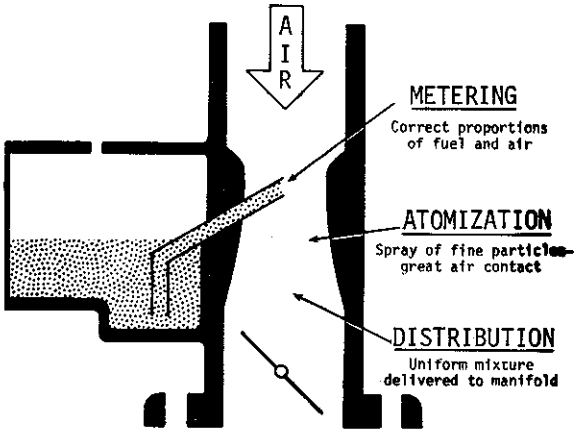


Figure 1-8. - Carburetor operation.

The intake strokes of the pistons create an airflow through the carburetor. This air-flow draws the fuel spray from the nozzle into the carburetor. The carburetor provides varying fuel-air ratios for such conditions as starting, warming-up, idling, and full power. It has a throttle valve which controls the carburetor fuel-air ratios. Look back to figure 1-2 to see how the carburetor is attached to the engine.

IGNITION SYSTEM

The gasoline engine uses a spark to ignite the air-fuel mixture. This occurs when compression is near its peak pressure. At the proper instant in the cycle, a hot electric spark jumps the spark plug gap and ignites the mixture.

The voltage of a starting battery is too weak (6 to 24 volts) to jump the spark plug gap. This low voltage is boosted by the IGNITION COIL. The coil is a step-up transformer that can boost the low voltage to peaks of between 10,000 and 20,000 volts. This is high enough to shoot a hot spark across the gap of a spark plug. The high voltage from the coil is fed into the DISTRIBUTOR. This device sends the high voltage to each cylinder spark plug at the proper time in the cycle. High voltage wires lead from the distributor to each spark plug. The major parts of an ignition system are shown in figure 1-9.

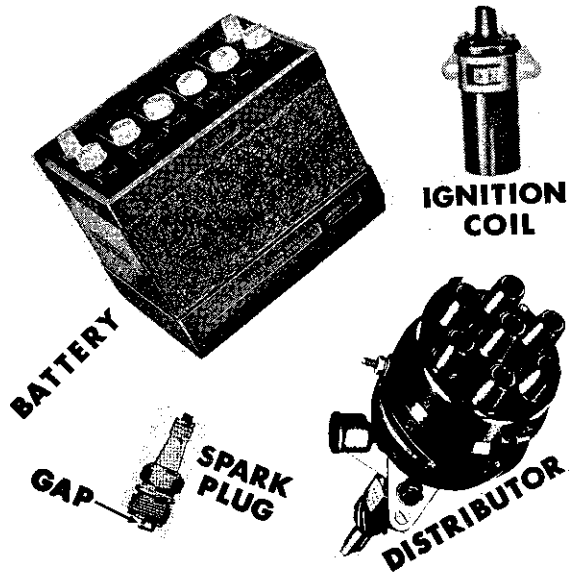


Figure 1-9. - Major parts of an ignition system.

The magneto is a self-contained unit used in some ignition systems. It is a high voltage electric generator. It is used for ignition in engines where a battery and generator are not needed for lights, etc. The magneto replaces the battery and coil in the standard system. It is for ignition alone. Engines that are handcrank started have them. You will find them on engine-driven pumps. Some engines have both magneto and battery-ignition systems. In these, if the battery goes dead, the engine can run on the magneto (figure 1-10).

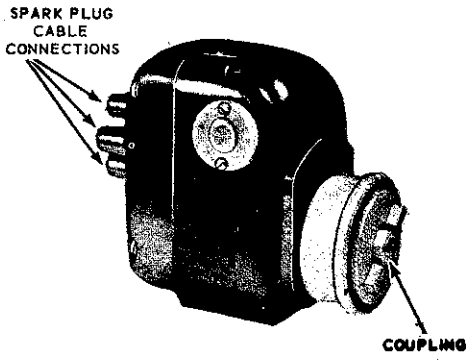


Figure 1-10. - Automotive magneto.

That's as far as we will go with ignition systems in this pamphlet. Now try the self-scoring questions on the next page before you move on.

REVIEW QUESTIONS

1. A carburetor's primary function is to _____.

   A. properly mix fuel with air
   B. direct air into the cylinders

2. A carburetor's operation is controlled by the _____.

   A. combustion chamber
   B. air flow
   C. piston strokes
   D. throttle valve

3. In the gasoline engine, the gasoline-air mixture in the cylinder is ignited by _____.

   A. heat of compression
   B. a spark plug
   C. a battery
   D. an ignition coil

4. In the gasoline engine, what device controls the sequence of a spark delivery to the cylinders?

   A. Coil
   B. Spark plug
   C. Battery
   D. Distributor

5. The primary source of voltage for the standard ignition system is the _____.

   A. generator
   B. battery
   C. coil
   D. transformer

Circle true or false in question 6. Correct any false statement.

6. In a standard ignition system, the coil does away with the need for a battery.

   TRUE/FALSE

_____

_____

ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	A. A carburator's primary function is to MIX FUEL WITH AIR.	1-13
2	D. The THROTTLE VALVE alters the air-fuel mixture according to demand.	1-13
3	B. In the gasoline engine, the gasoline-air mixture in the cylinder is ignited by a SPARK PLUG. The coil only supplies the high voltage. When this voltage jumps a gap in the spark plug, the cylinder mixture is ignited.	1-13
4	D. In the gasoline engine, the DISTRIBUTOR controls the sequence of spark delivery to the cylinders. The other choices are vital parts of any ignition system, but only the distributor regulates the sequence of spark to the cylinders.	1-13
5	B. The BATTERY is the primary source of voltage in the standard system. This is not true in the magneto system, however.	1-13
6	FALSE. The coil boosts the voltage of the battery high enough to jump the spark plug gap.	1-13

Now that you have the basics of the gasoline engine, let's move on to another engine. It works very much the same way.

THE DIESEL ENGINE

Diesel engines look very much like gasoline engines, but are usually much larger and heavier. They don't use a carburetor or ignition system.

Diesels come in two and four-stroke models. The cycles are the same as those of the gasoline engine. However, there are other major differences.

If a diesel doesn't have an ignition system, how does it ignite the fuel? And if it doesn't have a carburetor, how does the fuel get into the engine? How are the air and fuel mixed? A diesel ignites its fuel with very high temperatures. When air is compressed, its temperature rises. The air taken into a diesel engine is compressed to about 1/16th its normal volume. This causes the air to rapidly heat up to about 1,000°F. This is shown in figure 1-11. As the piston compresses the trapped air, the heat and pressure rise. When the piston has moved up to its highest point, the compressed air is very hot. Since diesel fuel ignites around 500°F, it can't be mixed with the air before entering the cylinder. A diesel's piston is near TDC (TOP DEAD CENTER) when fuel enters the cylinder through a fuel injector. It ignites from the high heat. The expanding gases force the piston downward on the power stroke.

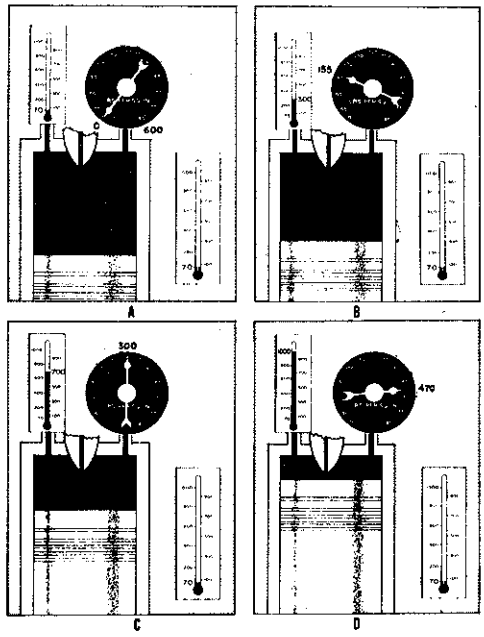


Figure 1-11. - Temperatures and pressures as compression occurs in a diesel engine cylinder.

The diesel, therefore, has no ignition system because the heat of compression ignites the fuel. It has no carburetor because the fuel is mixed with the air during injection. Figure 1-12 shows the fuel injector of a four-stroke diesel.

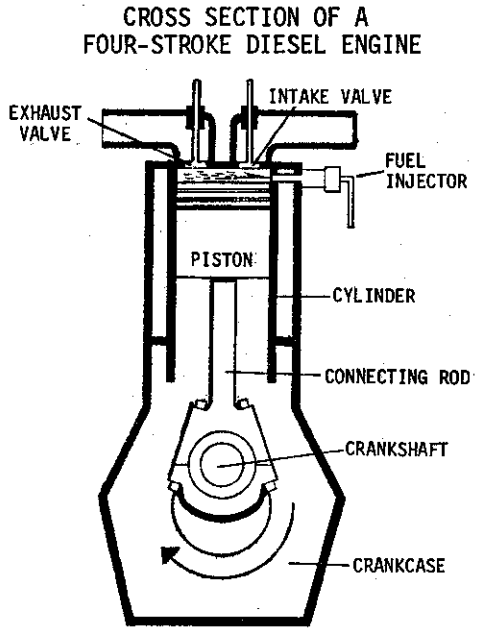


Figure 1-12. - Four-stroke diesel engine.

Some diesels have another major feature that you should know about. Air, instead of being drawn into the cylinder by the piston, is forced in. A BLOWER (also called a SUPERCHARGER) does this (figure 1-13). The air from the blower does four things. It forces the burned gases out of the engine through the exhaust. (This is called SCAVENGING.) And it fills the cylinder with fresh air. It also helps cool the cylinder. But the overall job of the blower is to increase power output.

In any engine, output power largely depends on the amount of fuel burned in each power stroke. Each ounce of injected fuel needs a certain amount of air to burn properly. The ordinary engine cylinder can only hold a certain amount of air. This limits the amount of fuel that can be injected for each power stroke. The result is limited power output.

Here's where the blower comes in. If air is blown into the cylinder under pressure, the cylinder is filled with more air than it could otherwise hold. (This is known as SUPERCHARGING). When this is done we can increase the amount of injected fuel. More fuel, more power, It's as simple as that.

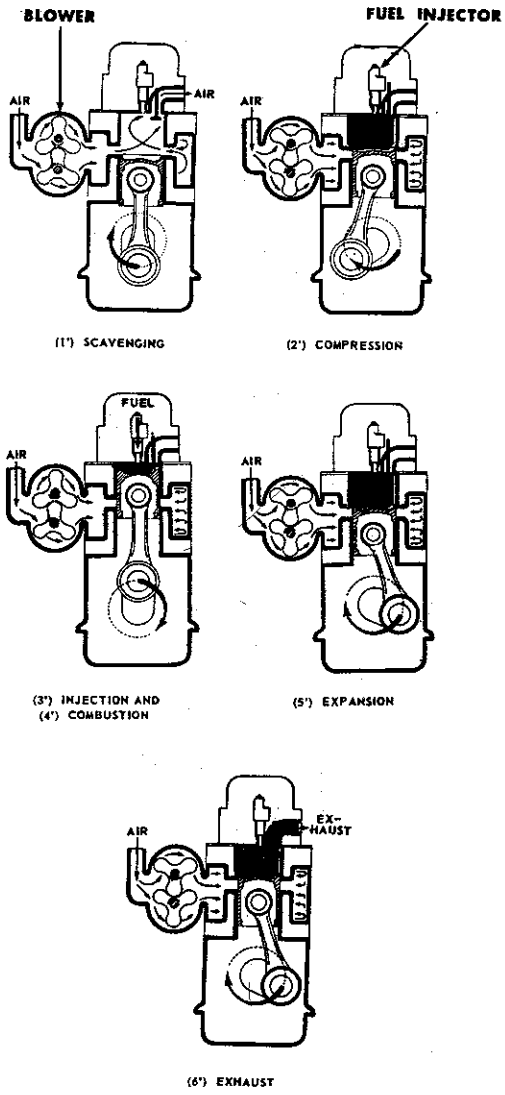


Figure 1-13. - Two-stroke diesel engine with blower.

Look at figure 1-13. The blower maintains air pressure against the cylinder. The air is admitted through many small holes in the cylinder. These holes are called ports.

The diesel has several advantages over the gasoline engine. The diesel develops more power from its fuel. You have no ignition system and no carburetion system to maintain. And don't forget about the safety of diesel fuel over gasoline. About the only disadvantage of the diesel is its size. Its higher pressures require that it be larger and heavier than the gasoline engine.

Get to know diesels. They are the main source of propulsion power in most Coast Guard ships.

Before we move on to the common systems of diesel and gasoline engines, test your knowledge of diesels with the self-scoring quiz on the next page.

REVIEW QUESTIONS

Circle true or false in questions 1 through 3. Correct any false statements.

1. A diesel engine's fuel is ignited by heat of compression.

   TRUE/FALSE

   _____
   _____

2. Superchargers and blowers are the same things.

   TRUE/FALSE

   _____
   _____

3. The chief disadvantage of the diesel compared to the gasoline engine is its size.

   TRUE/FALSE

   _____
   _____

4. What happens during the compression stroke of a diesel engine?

   A. Burned gases are expelled
   B. Fuel injection occurs
   C. Air is taken into the cylinder
   D. The cylinder is supercharged

5. The air in a diesel engine cylinder is compressed to about _____its original volume.

   A. 1/9
   B. 1/12
   C. 1/14
   D. 1/16

6. In a diesel engine cylinder, fuel is mixed with the air _____.

   A. in the injector
   B. during intake
   C. during scavenging
   D. in the cylinder

7. What does the diesel engine blower do?

   A. Charges the cylinder with air under pressure
   B. Cools the engine intake air
   C. Blows fuel into the engine
   D. Acts as an intake valve

ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	TRUE	1-17
2	TRUE	1-17
3	TRUE	1-18
4	B. During the compression stroke, FUEL INJECTION OCCURS. The other actions occur during different cycles.	1-17
5	D. In a diesel engine cylinder, air is compressed to about 1/16 ITS ORIGINAL VOLUME. The gasoline engine's compression is 1/9.	1-17
6	D. In a diesel engine cylinder, fuel is mixed with air IN THE CYLINDER. The injector sprays fuel into the air in the cylinder to form a burnable mixture.	1-17
7	A. The diesel engine blower CHARGES THE CYLINDER WITH INTAKE AIR.	1-17

COMMON SYSTEMS

This section covers two systems common to both gasoline and diesel engines. These are the cooling and lubricating systems. Both are vital to the operation of the engines. First, let's discuss the cooling system.

THE COOLING SYSTEM

The cooling system is one of the most vital systems in an engine. It keeps the engine working within the best heat range under all conditions. During combustion, gases reach 4,500°F. This heat is absorbed by the cylinder walls, pistons, and cylinder head. Excess heat must be removed. The cooling system does this.

Without a cooling system, an engine will get so hot that its lube oil will no longer be able to do its job. Moving parts will build up friction and heat until they gall and seize. The engine will stall and its moving parts will be damaged.

All engines run best when operated within a certain heat range. If an engine runs too cold, this can cause damage over a period of time. The cold-running engine gathers unwanted carbon. Cold lube oil is too thick to enter the tiny openings between some moving parts. Rapid wear occurs in a cold-running engine. Combustion gases can leak past the pistons of a cold-running engine and load the lube oil with trash and sludge.

The cooling system has an important job. It must keep engine heat in an exact range under all speeds and loads. We can't operate any engine without some type of cooling system. Let's look at the simplified cooling system in figure 1-14.

First, many passages surround the parts of the engine where the greatest heat is produced. These passages are called water jackets. A pump circulates the water through the water jackets. The water takes the heat from the engine. A device removes the heat from the water. The most common devices are radiators, coolers, and heat exchangers.

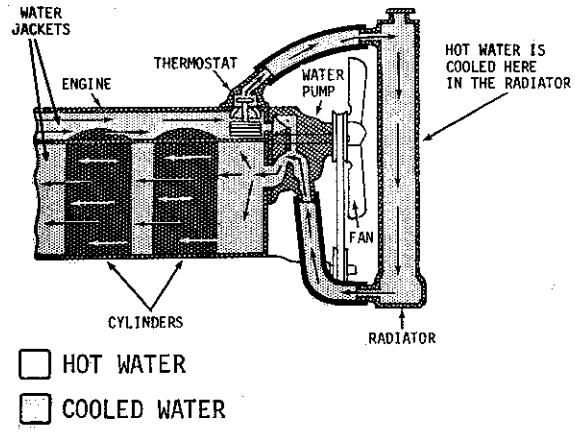


Figure 1-14. - Simple cooling system (Auto).

Look again at figure 1-14. Cool water is taken from the lower end of the radiator and pumped into the jackets inside the engine. The water picks up engine heat as it travels. As this heated water rises to the upper part of the engine, it reaches the thermostat. The thermostat senses the temperature of the water. If the water is too cool, the thermostat shuts off water flow until it reaches a certain temperature. Then the thermostat opens to let the water pass to the top of the radiator. As the hot water moves downward through the radiator, it is cooled. The water pump fan assists by blowing cool air through the radiator. From here, the water is then cycled through the engine again. This is the automotive cooling system. Aboard ship other systems are used. However, their jobs are the same.

In many shipboard systems the radiator is replaced by a heat exchanger that has a double set of passages. One set carries hot engine water, and the other carries cool seawater. The seawater carries away the heat and the engine water is recirculated.

The heat exchanger is also used not only to cool water, but also hot lube oil. This is as far as we go with cooling systems in this course.

Now quiz yourself with the questions on the next page before you move on.

REVIEW QUESTIONS

Circle true or false in question 1. Correct any false statement.

1. Engine water is cooled in the cylinders.

   TRUE/FALSE

   _____

   _____

2. Engine cooling water travels from the water pump into the _____.

   A. cylinders
   B. thermostat
   C. water jackets
   D. radiator

3. What device senses and controls engine water temperature?

   A. Fan
   B. Thermostat
   C. Radiator
   D. Water jacket

ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	FALSE. Engine water is cooled IN THE RADIATOR.	1-21
2	C. Engine cooling water travels from the water pump into the WATER JACKETS.	1-21
3	B. The THERMOSTAT senses and controls engine water temperatures. It opens and closes as the heat rises and falls.	1-21

LUBRICATING OIL AND THE LUBRICATING OIL SYSTEM

The lubricating oil system is another vital system in an engine. Its make-up varies with the engine model. Each system, however, moves lube oil through the engine. When we're finished, you should be able to explain the four main jobs of lube oil and trace its path through the engine. Let's begin with lube oil first.

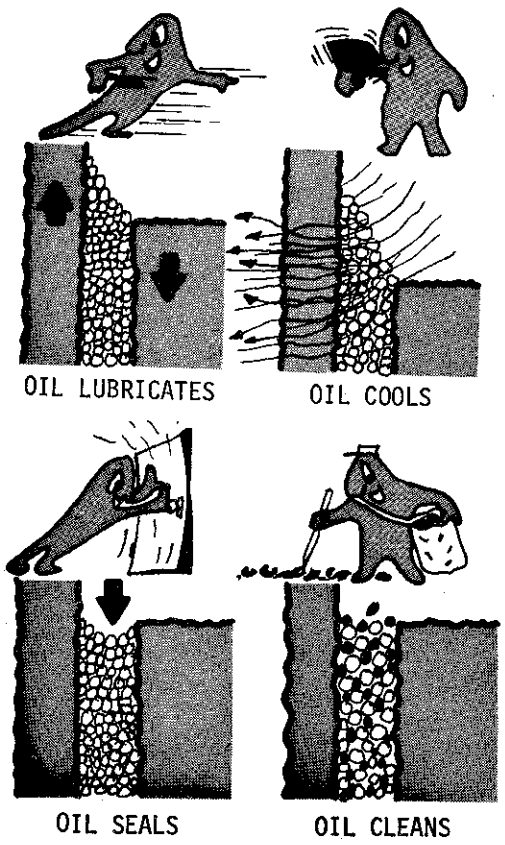


Figure 1-15. - Cartoon.

Lubricating Oil

As you can see in the cartoon (figure 1-15), the four main jobs of lube oil are:

1. It lubricates. This simply means that when placed between two rubbing surfaces, it reduces the friction. Without the lube oil, the two rubbing surfaces would soon get hot and the surfaces would become galled and damaged. Only a slight lube oil film is required to reduce friction. When a good oil film is placed between the surfaces, there is little or no physical contact between them. The film also absorbs shocks between the two surfaces.

2. It cools. Since friction is reduced there is less heat. Also the oil absorbs heat easily, making it a very good coolant. It goes through some very hot places in the engine and helps carry away excess heat.

3. Oil acts as a seal, especially between the piston and cylinder. It helps seal between the piston rings and cylinder walls.

4. Lube oil scavenges. This means that it picks up dirt and trash within the engine. It holds this dirt until the filter cleans it out. The lube oil tends to wash engine parts as it makes its way through the engine. The larger pieces of dirt settle to the bottom of the crankcase where they are drained away during oil changes.

The various grades of lube oils are suited for many jobs. You will learn the different kinds of lube oil in future courses.

Lubricating Oil System

Much can be written about the lubricating system of engines. Figure 1-16 shows the lube system of a small engine, whose path through the engine you can trace.

First, the oil is picked up from the crankcase, or sump, by the oil pump. Before it enters the pump it passes through a fine screen. This keeps the large pieces of dirt out of the system. Next it goes through the filter where the smaller pieces of dirt are removed. Then the oil, under pressure, enters the main oil gallery. The gallery branches off into many lines that feed the moving parts. Normally the oil first goes from the gallery to the crankshaft and connecting rod bearings. The next stop is usually the camshaft. Then the oil travels toward the top of the engine where it oils the rocker arms, shaft and valve stems.

Other internal parts such as gears, etc., are normally only splashed with oil. After the oil reaches the top of the engine, it drains through special passages back down into the sump. If the oil is too hot to be used again, it is run through a cooler.

In some large diesel engines the oil is drained into a sump outside the engine. This is a dry sump. The system described before uses a wet sump, which is a part of the engine. There is another system which is used in small two-cycle gasoline engines.

Figure 1-7 illustrated the actions of the two-stroke cycle action. The figure showed the air-fuel mixture's route through the engine crankcase and

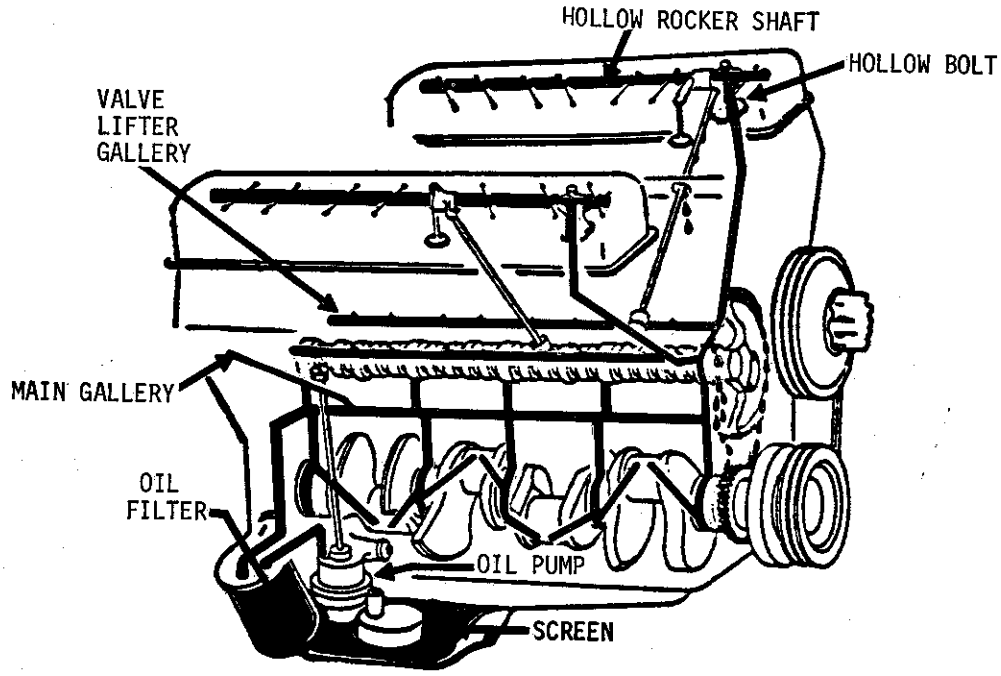


Figure 1-16. - Engine lubricating system.

intake ports and into the cylinder. This engine has no lube oil sump. The engine crankshaft, cylinder, and piston, can't function long without oil. How, then, is lubrication performed? The oil is mixed with the fuel before it is put into the fuel tank. When the fuel-oil mixture goes through the carburetor, it becomes an air-fuel-oil mixture. When this mixture enters the crankcase, the lube oil comes in contact with the moving parts. As the engine runs and gets warm, the fuel tends to vaporize more in the crankcase. This allows most of the heavier lube oil in the mixture to drop onto the moving parts. Some of the lube oil, however, is carried into the cylinder and burned.

When you see oil being mixed with the gas for a small engine, you can be fairly sure the engine is two-cycle. If you are told to prepare fuel for this type engine, make sure you add the required amount of oil.

Complete the review questions on the next page before you go on to the next section.

REVIEW QUESTIONS

Circle true or false in questions 1 through 3. Correct any false statements.

1. Lube oil eliminates friction.

   TRUE/FALSE

2. A small two-cycle gasoline engine has a wet sump.

   TRUE/FALSE

3. In a wet sump engine, the lube oil is in the engine.

   TRUE/FALSE

4. After leaving the main oil gallery, the oil usually goes first to the _____.

   A. rocker arm
   B. valve stems
   C. filter
   D. crankshaft

5. The four main jobs of lube oil are _____.

   A. cooling, lubricating, sealing, and scavenging
   B. cleaning, heating, bonding, and sealing
   C. bonding, sealing, lubricating, and cooling
   D. lubricating, heating, bonding, and scavenging

ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	FALSE. Lube oil REDUCES FRICTION.	1-25
2	FALSE. A small two-cycle gasoline engine has a DRY SUMP.	1-25
3	TRUE.	1-25
4	D. After leaving the main oil gallery, the oil usually does first to the CRANKSHAFT.	1-25
5	A. The four main jobs of lube oil are COOLING, LUBRICATING, SEALING, and SCAVENGING.	1-25

THE GAS-TURBINE ENGINE

A turbine will work as long as an energy source is found that will turn the ROTOR. Think of a hand-held toy windmill. You can either blow on it or hold it in front of a fan to make it turn. Both energy sources make it work. In a steam turbine, hot steam under great pressure is used to turn the turbine rotor.

More recently, another means of turning the turbine has been developed. It is designed to overcome some of the disadvantages of the steam turbine. The steam turbine needs very large boilers and heavy pipes in order to work. It cannot be used in some instances because of its size.

The new turbine does away with the boiler by using a new energy source to turn the rotor. It burns diesel fuel or aviation jet fuel and uses the hot gases to turn the turbine. The engine is called a gas turbine because it turns the rotor with hot expanding gases. Look at figure 1-17. There are actually two parts to the gas turbine. Look at figure 1-17 again. "The front has an opening for air to enter the engine." A set of blades is attached to the rotor of the COMPRESSOR. "The rotor turns at very high speed and draws air into the engine. It compresses the air into the COMBUSTION chamber." Here fuel is injected into the air. A spark now occurs at the gap of an IGNITER PLUG and a very hot flame starts to burn. This heats the air and increases the pressure even more. This mixture of hot gases and air is forced out of the combustion chamber at very high speeds. The hot gas mixture strikes the turbine rotor blades and turns the rotor.

Notice that the compressor blades in the front and the power turbine blades at the rear are both attached to the same rotor. When the hot gases leave the combustion chamber, they drive the rotor. This compresses the incoming air. Because one rotor can be used both to compress the air and to produce power the gas turbine engine is very efficient. The gas turbine is most efficient at full load when its temperature and pressure are high.

On our modern ships using the gas-turbine engine for propulsion, the jet blast is changed to mechanical energy by a FREE TURBINE. Look at figure 1-18. The free turbine is an extra turbine placed behind the high pressure turbine and not connected to the turbine rotor. The free turbine is driven by the high-speed exhaust gases from the gas turbine. The free turbine is connected to the main-propulsion shaft through the free-turbine shaft, a clutch, and a reduction gear.

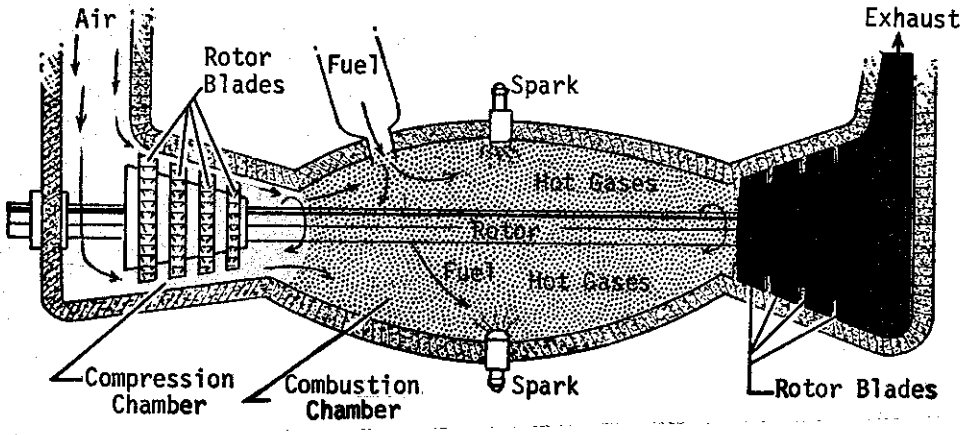


Figure 1-17. - Simplified gas-turbine engine.

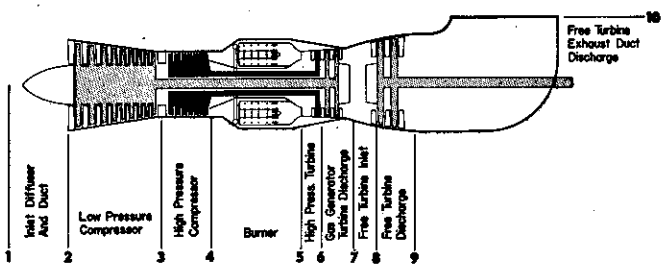


Figure 1-18. - Gas turbine and free turbine.

ADVANTAGES OF A GAS TURBINE

The gas-turbine engine has many advantages over the steam turbine. The gas turbine can be made relatively small and light. Yet its power output is very large. It has no pistons, valves, coils, or distributors. The engine burns a lower and less costly grade of fuel than does the gasoline engine. It is a very efficient engine since the main parts rotate rather than reciprocate. It develops high horsepower and does not wear out as fast as the reciprocating engine.

The main disadvantage of the gas-turbine engine is fuel consumption. The gas turbine is a real fuel gulper. It uses fuel at a much higher rate than other engines of equal size.

Because of the high heat and engine speeds, other problems have also arisen. One such difficulty is the noise that the turbine makes. The noise from the thrust of the engine has been quieted to some extent. The high-pitched whine from the engine, however, has proven to be a problem for personnel working around the engine. Some people have suffered a high-frequency hearing loss due to this noise. Wear ear protection when working around this engine!

Finally, when a gas turbine is running, dirt and foreign objects from the surrounding air may be drawn into the engine. When this happens, the engine can be torn apart due to the high speed of the rotating parts.

USES OF GAS TURBINES

New uses for this engine are being found every day. It is used to power experimental automobiles, provide emergency and standby power for electric generators, and operate huge pumps and compressors in industry. Also, it provides extra power for rescue operations on Coast Guard high and medium-endurance cutters.

This is as far as we will go with gas-turbine engines in this course. Now try these questions.

REVIEW QUESTIONS

1. What drives the rotors in a gas turbine?

   A. Compressed air
   B. Free turbine
   C. Expanding burning gases
   D. Reduction gears

2. In a gas turbine, which turns the compressor, the rotor shaft or inrushing air?

   _____
   _____

3. The gas turbine is a/an _____ engine.

   A. reciprocating
   B. rotating
   C. external combustion
   D. low efficiency

4. The main disadvantage of the gas-turbine engine in comparison with other engines is its _____.

   A. internal temperatures
   B. low horsepower
   C. high fuel consumption
   D. high speeds

ANSWERS TO REVIEW QUESTIONS

QUESTION	ANSWER	REFERENCE
1	C. EXPANDING GASES in the combustion chamber drive the rotors in a gas turbine.	1-29
2	The ROTOR SHAFT turns the compressor.	1-29
3	B. The gas turbine is a ROTATING engine.	1-30
4	C. The main disadvantage of the gas-turbine engine in comparison to other engines is its HIGH FUEL CONSUMPTION.	1-30

PAMPHLET REVIEW QUIZ

1. Which internal combustion engine fuel is rated by CETANE number?

   A. Gasoline
   B. Diesel
   C. Kerosene
   D. JP-5

2. What fuel(s) is/are used in the shipboard gas turbine?

   A. Aviation jet fuel only
   B. Diesel fuel only
   C. Gasoline
   D. Aviation jet fuel and diesel fuel

3. In a reciprocating engine, the reciprocating action of the piston and connecting rod are changed to a turning motion by the _____.

   A. exhaust valve
   B. carburetor
   C. cylinder
   D. crankshaft

4. The stroke sequence of the four-stroke-cycle engine is _____.

   A. intake, power, compression, exhaust
   B. compression, power, intake, exhaust
   C. compression, exhaust, power, intake
   D. intake, compression, power, exhaust

5. In a four-stroke-cycle engine, the piston always travels toward the cylinder head during the _____ strokes.

   A. intake and exhaust
   B. intake and power
   C. power and exhaust
   D. compression and exhaust

6. In a four-stroke-cycle engine, both intake and exhaust valves are closed on the _____strokes.

   A. intake and exhaust
   B. exhaust and power
   C. power and compression
   D. compression and exhaust

7. After leaving the carburetor, the air-fuel mixture then goes to the _____.

   A. intake ports or valve
   B. exhaust ports or valve
   C. piston and connecting rod
   D. cylinder and piston

8. In the two-stroke-cycle engine, the exhaust and intake events occur during the _____stroke.

A. power
B. compression
C. intake
D. exhaust

9. A two-stroke-cycle engine can be readily recognized by its _____.

A. cylinder head
B. intake and exhaust valves
C. cylinder ports
D. carburetor

10. How can a two-stroke-cycle diesel engine be identified?

A. Injectors
B. Carburetors
C. Intake valves
D. Cylinder ports

11. In gasoline internal combustion engines, the fuel mixture in the cylinder is ignited by a _____.

A. compression
B. spark plug
C. carburetor
D. piston

12. What device boosts the low voltage in the battery ignition system on internal combustion engines?

A. Magneto
B. Ignition plug
C. Distributor
D. Ignition coil

13. What device sends an ignition spark to the spark plug at the correct instant?

A. Ignition coil
B. Battery
C. Distributor
D. Timer

14. The magneto is a device similar to a/an _____.

A. electric generator
B. electric motor
C. spark plug
D. distributor

15. In a four-stroke-cycle gasoline engine, fuel is mixed with air in the _____.

A. carburetor
B. cylinder
C. piston
D. intake valve

16. What is used to ignite the fuel in a diesel engine?

A. Spark plug
B. Ignition coil
C. Heat of exhaust
D. Heat of compression

17. What device adds fuel to a diesel engine cylinder?

A. Carburetor
B. Distributor
C. Injector
D. Igniter

18. What device applies air pressure to the intake of an operating diesel engine?

A. Carburetor
B. Intake ports
C. Blower
D. Compressor

19. What is the main function of a supercharger?

A. Increasing engine output
B. Scavenging burned gases
C. Controlling engine speed
D. Mixing the air and fuel

20. What is the function of an engine cooling system?

A. Dissipate all engine heat
B. Maintain a specific operating temperature
C. Eliminate friction of the moving parts
D. Maintain cylinder compression

21. In a simple cooling system, the thermostat _____.

A. cools the water
B. circulates the water
C. regulates water temperature
D. absorbs engine heat

22. What are four main functions of lube oil?

A. Cools, cleans, lubricates, seals
B. Lubricates, scavenges, heats, seals
C. Seals, cleans, insulates, lubricates
D. Insulates, cools, lubricates, seals

23. An engine where the lube oil is stored in the crankcase of the engine is called the _____type.

A. dry sump
B. self-contained
C. wet sump
D. gallery

24. When lube oil leaves an engine sump, it goes through a _____.

A. filter
B. screen
C. gallery
D. branch line

25. In a two-stroke-cycle gasoline engine, where is the lube oil placed?

A. Wet sump
B. Dry sump
C. Main gallery
D. Fuel tank

26. In a gas turbine, how is the burning fuel used to develop mechanical energy?

A. The compressor turns the rotor
B. Burner cans turn the compressor blades
C. Expanding gases turn the turbine blades
D. The burners direct gases into a cylinder

27. What is the function of the free turbine?

A. Drives the compressor
B. Converts energy of the engine exhaust into mechanical energy
C. Converts mechanical energy of the engine into rotary motion
D. Drives the high pressure turbine

28. What is the main disadvantage of the gas turbine engine?

A. High fuel consumption
B. Excessive heat
C. Large size
D. Vibration

PAMPHLET REVIEW QUIZ
ANSWER KEY

QUESTION	ANSWER	REFERENCE
1	B	I-1
2	D	I-1
3	D	I-2
4	D	I-2-3
5	D	I-2-3
6	C	I-2
7	A	I-2
8	A	I-7
9	C	I-7
10	D	I-7
11	B	I-13
12	D	I-13
13	C	I-13
14	A	I-13
15	A	I-13
16	D	I-17
17	C	I-17
18	C	I-17
19	A	I-17
20	B	I-21
21	C	I-21
22	A	I-25
23	C	I-25
24	B	I-25

25	D	1-27
26	C	1-29
27	B	1-29
28	A	1-30

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